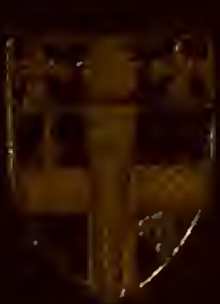

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ON THE

MINUTE STRUCTURE OF THE LUNGS,

AND ON THE

FORMATION OF PULMONARY TUBERCLE.

By GEORGE RAINEY, Esq., M.R.C.S.,
MICROSCOPIST OF ST. THOMAS'S HOSPITAL.

Communicated by RICHARD D. GRAINGER, Esq.

Received February 11th,—Read March 25th, 1845.

The lungs are made up of bronchial tubes, bronchial intercellular passages, and air-cells.

On the bronchial tubes and intercellular passages.—The bronchial tubes commence at the bifurcation of the trachea. They are composed of cartilaginous rings and a proper membrane. They ramify in the substance of the lungs, their cartilaginous rings gradually disappearing; and in the human lung, having arrived within about one-eighth of an inch of its surface, the membrane also terminates, but somewhat abruptly,* after which the passages conducting the air continue in the same direction as the bronchial tubes, of which they are the continuation, but without having any perceptible membranous lining; their parietes being formed merely by the air-cells between which they pass and by which they are surrounded.

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* See Plate V., fig. 1.

The membrane of the bronchial tubes retains its fibrous character as far as its termination, the fibres being arranged longitudinally and circularly, and also its lining membrane. These are supplied by a distinct set of blood-vessels, which at the termination of the membrane anastomose with the vessels of the air-cells. The diameter of the ultimate bronchial tubes is from $\frac{1}{50}$ to $\frac{1}{30}$ of an inch. They communicate with but few air-cells, and at these communications their membranous lining is not continued into these cells, but, on the contrary, the vessels of the cells pass into the bronchial tubes, and ramify very superficially on their inner surface, probably to allow the blood within them to be acted upon by the inspired air.

The bronchial intercellular passages are at first of a circular form, and, like the bronchial tubes, do not communicate with many air-cells; but as they approach the surface of a lobule, the number keeps increasing, and at length these openings of communication are so numerous, and so near together, that the intercellular passage loses altogether its circular figure, and becomes reduced to an irregularly-shaped passage, running between the air-cells, and communicating with them in all directions; lastly, having arrived close to the surface of a lobule, it terminates in an air-cell, which is not dilated, as stated by Reisseissen, but has about the same diameter as the passage of which it is the continuation.* The epithelium (ciliated) which is peculiar to the air-passage, lines the bronchial tubes as far as the termination of the bronchial membrane, but it does not appear to extend beyond the membrane into the bronchial intercellular passages, or into the air-cells. The smallest tube in which I have seen the ciliated epithelium, had a diameter of about $\frac{1}{30}$th of an inch, but I have never found it in a tube where the bronchial membrane was not present also. As the lung near its surface is made up entirely of air-cells and intercellular passages, the contents of these can easily be examined, without there being any admixture of the epithelial lining of the bronchial tubes, care being taken only to select for examination those portions of the lung which lie immediately beneath the pleura. I have repeatedly examined these parts of the lung, but have not found this kind of epithelium. In the healthy lung, black pulmonary matter is present in greater or less abundance in the air-cells, as well as in the cellular tissue, distending the interlobular fissures and adhering to the external surface of the blood-vessels; and, in the diseased lung, granular matter may sometimes be found in the intercellular passages and air-cells, but it has not the character of ciliated epithelium.

In the uninjected lung, the remains of nucleated cells in the walls of the capillaries have a sufficient resemblance to epithelium to be easily mistaken for it. Mr. Addison seems, from the following observation, to have fallen into this error:—"They (the air-cells) possess an epithelium, in the form of round nucleated scales, and from one to fifteen or more nuclei may be counted in a single scale." Mr. Addison, however, adds,—"But I have never satisfied myself that they possess the ciliated cylinder epithelium, so abundant in the trachea and bronchi."*

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* See Plate V., fig. 2.

From what has been stated, it appears that the upper part only of the air-passages is lined by mucous membrane, and it will be shown hereafter that those parts in which the aeration of the blood more particularly takes place, are lined only by a very thin fibrous membrane. These facts seem to agree with the phenomena presented by acute inflammation of these structures, inflammation of the bronchial membrane (bronchitis) being attended by the symptoms peculiar to inflammations of other mucous membranes, and inflammation of the membrane lining the air-cells (pneumonia) being accompanied by deposition of fibrine, as in inflammation of the common fibro-cellular tissue.

The existence of a difference in structure between the membrane lining the bronchi and that lining the air-cells was long ago inferred, and insisted upon, by Dr. Addison and others, from pathological considerations; but, I believe, the fact has not been *demonstrated.*

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* Philosophical Transactions, 1842, Part II., p. 162.

On the air-cells.—The air-cells are small, irregularly-shapen, and, most frequently, four-sided cavities, varying in size in different parts of the same lung, those being the smallest, as well as the most vascular, which are situated nearest its centre, whilst their size gradually increases, and their vascularity diminishes, as they extend into the more remote parts. This difference in size and vascularity of the air-cells is probably for the purpose of adapting the quantity of blood requiring to be decarbonized, to the deteriorated condition of the air in the differently situated cells. The renovation of the contents of the more superficial cells taking place more slowly than that of the contents of the more central ones—it being in the former effected by the passage of the air from the terminal into the more central cells (in consequence of the law of diffusion of gases), and in the latter, chiefly by the mechanical dilatation and contraction of the thorax,—it is necessary that there should be a proportionally small quantity of blood circulating through the former, than through the latter.

The air-cells which are situated close to the bronchial tubes, or intercellular passages, open into them by large circular apertures, whilst those which are placed further from these passages communicate with them through the medium of other cells. These communications of one cell with another are of the same shape and size as those which exist between the first set of cells and the bronchial tubes; and they can be seen very distinctly by looking into the air-cells from the intercellular passages, and regulating the distance of the object-glass according to their different depths. As these openings are not necessarily in a straight line, the exact quantity of cells which communicate cannot in this manner be determined, but the number will depend upon the distance which intervenes between any given part of a bronchial passage and the surface of a lobule; so that, when a bronchial passage arrives nearest the surface, it will be separated from it only by a terminal cell, as before observed.

Besides these intervening air-cells, there are others which fill up the angle formed by the bifurcation of the intercellular passage, and which thus appear to form a cellular communication between them.

It is very easy, in an injected preparation, to see the communication between two, or sometimes three cells; but, to determine with exactness the number of cells which communicate in succession, is probably impossible, in consequence of the section which is favourable for displaying the opening of one, being unfavourable for displaying that of the other; but, that the communications between the cells of the same lobule are very free, is obvious from the fact, that, if injection be thrown into a small bronchial tube, it will distend all the cells of that lobule, while none of the injection will pass into the adjoining lobules. In the mammal, the walls or partitions by which the air-cells are separated from one another, consist of a single plexus of vessels enclosed in a fold of membrane, whilst the sacculi of the lung of the reptile, which may be considered to correspond to the air-cells in the lung of the mammal, are separated by a plexus folded on itself, and, therefore, consisting of two layers of vessels, a character by which the lung of the reptile differs from that of the mammal.

The plexuses in the lungs of the reptile and mammal consist alike of a very dense net-work of capillaries, into which terminal branches of the pulmonary arteries terminate, and from which the radicles of the pulmonary veins take their origin.

In the latter—the mammal—the number of capillary plexuses is not, as some have supposed, the same as that of the air-cells, that is to say, a terminal artery does not divide into a plexus at any particular part of a cell, its branches uniting for the commencement of a vein on the opposite part. On the contrary, one plexus passes between, and supplies several cells. In the interior of the lung, the exact extent of an individual plexus cannot be determined, in consequence of the removal of some part of it by the section necessary for its exhibition. But, on the surface of the lung where the extent of these plexuses, in relation to the cells over which they ramify, can be easily made out, an individual plexus may be seen to spread over an area of ten or twelve cells in some parts, and fewer in others, the exact number depending, in some measure, upon the size of the cells.

Here, after the pleura has been removed, the terminal arteries may be observed descending from the interior of the lung between the cells to the surface, where they send off their branches in all directions, some anastomosing with the adjacent branches of the pulmonary artery, and others terminating in the radicles of the pulmonary veins.

On that side of a cell in which is situated the opening of communication with an adjoining one, the capillaries anastomose all around this opening, so as to appear in the injected preparation, by reflected light, to form its immediate boundary; but by transmitted light, this opening will be seen to be formed by circular threads of the lining membrane of the air-cells, which extend beyond the circle of vessels.* To these communications, Mr. Addison has given the name of "lobular passages," under the idea that no air-cells exist in the fœtal lung, but that they are formed after birth by the mechanical dilatation of the bronchi.

The incorrectness of this notion is obvious from this fact, that the air-cells, with the capillary plexuses between them, are perfectly developed in the lungs of animals which have died two or three days after birth; for, in such cases, it cannot be supposed that these vessels could have been formed in so short a time as that which had elapsed between the birth and death of the animal, even had the parietes of the bronchi been dilated in the manner supposed by Mr. Addison.

With a view of settling this question, at the suggestion of Mr. Grainger, I injected the lungs of various fœtal animals, which had never breathed, and found, upon examining them with the microscope, that the air-cells were developed proportionally with the other parts of the lungs.

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* See Plate V., fig. 3.

In the very young fœtus, the septa between the air-cells consists almost entirely of minute cellules or granules, and a small quantity of fibrous tissue, with scarcely any blood-vessels, so that the injection, which had been thrown into the pulmonary artery and extended into these vessels, became extravasated among the granules situated between the air-cells.

As the age of the fœtus advances, the granular matter diminishes, and the capillaries increase, so that at birth, the same arrangement of the air-cells and the other parts of the lungs exists as in after-life.

It has already been stated that the capillaries of the lungs are situated in a fold of membrane.* Proceeding with a description of this membrane, from the peripheral to the central parts of these organs, it may be described as lining, first the air-cells, which are next to the surface of a lobule, that is, those which are situated immediately beneath the pleura, and those which bound the interlobular fissures, being separated merely by the capillaries from the pleura in the one situation, and by the capillaries from the interlobular areolar tissue in the other.

From these cells it passes into the next set, enclosing the capillaries, which are situated between them, and forming the immediate boundary of the opening by which they communicate: thence extending from one cell to another, it arrives at the intercellular passages, and, at the termination of the bronchial tubes, becomes confounded with the bronchial membrane.

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* See Plate V., fig. 3.

This membrane is so thin and transparent that it can be seen only by transmitted light; it is distinctly fibrous; its fibres are strongest and best marked the nearer they are situated to the openings of communication between the air-cells, and some circular fibres extending a little beyond the vascular anastomoses which surround those openings, form their well-defined border.* This membrane besides lining the air-cells, and supporting the capillary plexus, will serve especially by means of its circular fibres to keep the openings into the cells patulous. Its structure has no resemblance whatever to muscular fibre, either of the striped or unstriped kind.

On the formation of pulmonary tubercle.—Having now considered the anatomy of the lungs, I will proceed to speak of the formation of pulmonary tubercle, and to show the manner in which the tuberculous deposit takes place, and extends itself by the destruction of the various parts of the lungs.

In order to determine with accuracy the precise situation of tuberculous matter, and to observe the manner in which the lungs become progressively destroyed by its presence, it is advisable to examine tuberculous lungs which have been successfully injected.*

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* See Plate V., fig. 3.

In such preparations, when viewed by reflected light, the pale colour of tuberculous matter contrasts so strikingly with the red colour of the injection in the capillaries of the walls of the cells, that there is no difficulty in discerning its exact form and limit, even in quantities so small as to fill only one, or even a small portion of a cell.

By this mode of examination, it will be clearly seen that the tuberculous matter is poured from the free surface of the pulmonary membrane into the interior of the air-cells. These becoming distended, and the septa between the contiguous cells being at first compressed, and their vessels afterwards obliterated, the supply of blood to the diseased part is cut off, and a tubercle formed, corresponding in size to the number of distended cells.

The manner in which tubercles extend themselves to the parts adjacent is best seen by observing the progress which had been made by the deposition in the air-cells situated in their vicinity. Here some of these cells will be seen to contain only a small quantity of deposit, others to be completely distended with it, though their vascular walls remain entire. Between other cells containing tuberculous matter, these vessels will be seen to have become partially obliterated; and lastly, in the septa, between those cells where the accumulation has amounted to such a quantity as, generally, to compress the capillaries, and probably cause their absorption, no vessels are left, and nothing exists but the pulmonary membrane, which remains mixed with the tubercular matter, and which (the tubercle having been broken up) is in a state to be ejected from the lungs in the expectoration, in which it can be detected by the microscope.

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* See Plate V., fig. 4.

An imperfect examination of the vascular connection of a tubercle with the surrounding air-cells, in the injected lung, might give the idea of vessels passing into it from the adjacent unaffected parts, and thus lead to the supposition that it is vascular,—an idea which has long been prevalent among pathologists. A careful examination, however, clearly shows that these vessels are merely portions of plexuses which have not yet become absorbed. In most cases, these vessels will appear as arcs of circles of greater or less extent, of the same radius as the plexuses between the air-cells, of which they are, obviously, the remains.

The deposit of tuberculous matter takes place in the bronchial intercellular passages at the same time and in the same way as in the air-cells; and their walls,—which are in reality the air-cells between which they pass,—disappear in the same manner as those which separate one cell from another; and thus these passages being occupied by tuberculous matter, contribute to form a part of the tubercle. The smaller bronchial tubes also becoming distended with tuberculous matter, are involved in the general mass.

It will be obvious from what has preceded, that as a tubercle increases in size, the central parts of it will become further and further removed from those vessels, by which the tuberculous matter was in the first instance deposited, and afterwards maintained in a state of vitality, and consequently these parts will have the greatest tendency to lose their cell or vegetable life, and become softened. According to this explanation, this process ought always to begin in the centre of a tubercle, and I believe this is generally the case. But it must be recollected that the geometrical centre of the mass is not necessarily the point furthest removed from the source of circulation ; the point may even be on the side of the tubercle, provided it be the remote cells of a lobule which are occupied by the tuberculous matter, namely, those bounded by an interlobular fissure : in such a case, this part of the tubercle might be further removed from the source of circulation, than its exact centre.

Some pathologists contend that tubercle is the result of inflammation. Without entering at length upon the consideration of this question, which is one *de verbo* and not *de re*, I may state that the perfectly natural appearance of the vessels close to a tubercle, and even of the cells containing a small quantity of tubercular matter, not sufficient to have impeded their circulation in the capillaries during life, when compared with the tortuous and unequally dilated state of vessels going to air-cells filled with fibrine, in consequence of inflammation, are pathological considerations in favour of the non-inflammatory nature of phthisis. These facts go also to show that the obliteration of the capillaries between the air-cells is, in phthisis, produced by some force which has exerted upon them a slow and very gradual compression, such as can only be conceived to have been produced by the accumulation of tuberculous matter, in contiguous cells, pressing upon the intervening plexuses.

I may observe, that the facts I have mentioned refer only to the most ordinary description of phthisis, and that they are the result of a great number of examinations; and I contend that they prove that this form is not at all connected with other forms, and that it is erroneous to suppose that miliary is necessarily the incipient state of common tubercle. My preparations, as well as those of Mr. Quekett, show that the progress of this tubercle, from its commencement up to its perfect formation, depends, simply, upon the quantity of the deposit; for it can be seen, in some parts, occupying only a part of a cell, in others, one, two, three, or even of an indefinite number, and, in every case, to exhibit the same microscopic characters.

In this form of phthisis there appear to be two pathological states from which we can deduce an explanation of its symptoms:—first, a portion of lung is rendered impermeable to the blood; secondly, the blood is thrown upon the surrounding unaffected parts.

Whether the first of these states ought to be regarded as inflammation, or not, must ultimately remain a matter of opinion, so long as the term "*inflammation*" has no definite signification.

Without doubt, it is to the second state as a mere consequence of the first, that the attacks of hæmoptysis are due, as well as the susceptibility to severe and obstinate catarrhal symptoms. The tuberculous matter, acting like an extraneous body, will produce a constant tendency to inflammation, and, after it has been produced, prevent its removal. Hence will follow those hectic and other symptoms which result from the continued operation of any irritating body.

As regards the expectoration, this will occur most frequently from the bronchial membrane, and, most probably, is not to be distinguished from that in ordinary bronchitis. It will be only during the breaking up of a tubercle that matter truly tuberculous will be expectorated, and this, I believe, can be recognized, with certainty, by no other character than its containing fragments of the membrane of the air-cells.

P.S.—Since this paper was communicated to the Society, I have met with an instance in which tubercles existed in the lungs, liver, kidney, mesentery, and other parts,—all evidently of a scrofulous character. I injected the animal (a rabbit) with fine injection. Some parts of the lungs were studded with white masses of different sizes; others, even as much as the third of a lobe, appeared very much like a lung which had never respired. On examining the latter, I perceived in the arterial trunks leading to those parts, distinct masses of white granular matter mixed with the injection; and, continuing the examination, I found that this appearance was due to all the capillaries being, literally, choked up with this same matter. The air-cells were free from it, and contained air. The white masses in the other parts appeared to be produced by the vessels being filled with this matter, as in the preceding, and also by its escape into the air-cells and surrounding structures. On examining the kidney, I found that the vessels were filled in the same manner as in the lungs. I mentioned this to Mr. Quekett, who told me that he had, in scrofulous cases, seen strumous matter mixed with blood, which had been pressed out from an artery going to a diseased part.

[*From Transactions of Medico-Chirurgical Society*, Vol. xxviii.]

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EXPLANATION OF THE PLATE.

Fig. 1.—Shows the abrupt termination of a bronchial tube in a bronchial intercellular passage.

a The bronchial membrane.

b The opening of an air-cell into a bronchial tube, with the capillaries surrounding it.

Fig. 2.—The course and termination of a bronchial intercellular passage.

a a Its commencement and termination.

b An air-cell opening into it.

Fig. 3.—The pulmonary membrane enclosing the capillary plexuses highly magnified.

a The plexuses.

b The free margin of the membrane, projecting beyond the vessels, and forming the immediate boundary of the opening of one air-cell into another.

Fig. 4.—The tubercular matter situated in the air-cells with the remains of the capillary plexuses between the cells.

a The tubercular matter.

Fig 1.

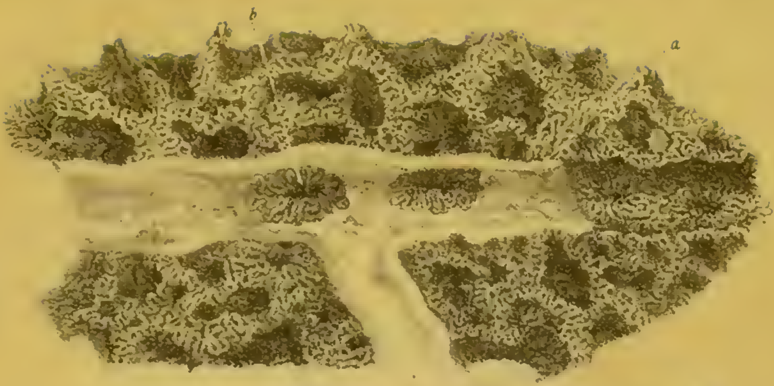
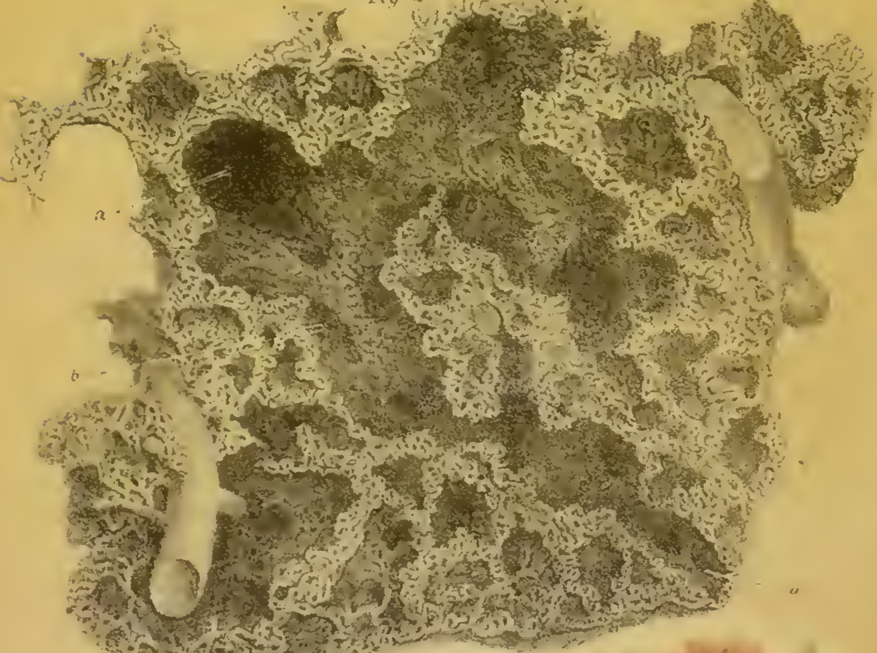


Fig 2



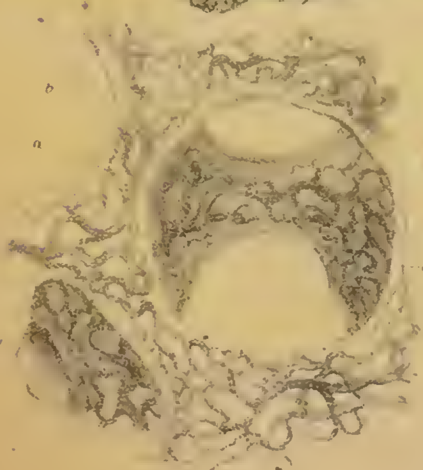


Fig 3

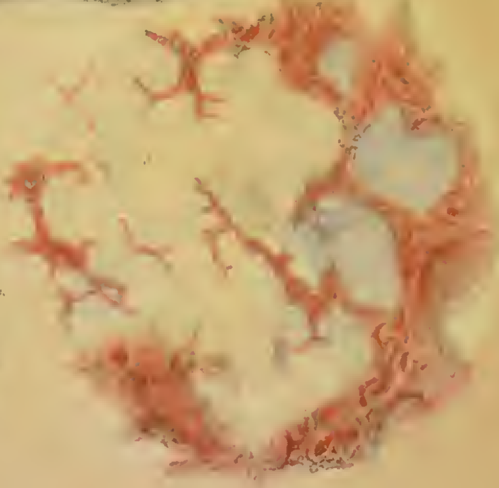


Fig 4

n Nature & on Stone by W.H. Kearney.

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